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## HIGH EFFICIENCY SORTING CONVEYOR

### Background of the Invention

#### (1) Field of the Invention

5 The present invention relates generally to package sorting conveyors and more particularly relates to a sorting conveyor having greatly improved energy efficiency.

#### (2) Description of the Related Art

10 Conveyor systems having a number of individual carrying carts have been commonly used for many years to carry and sort packages or other items, such as mail. For example, U.S. Patent No. 5,054,601 to Sjogren et al. discloses a package sorting conveyor comprised of a train 15 of tilt tray carriers coupled in tandem to form a continuous loop. Each carrier includes a pivotally mounted tilt tray normally maintained in an upright position. The carriers are moved around the loop by a series of motors spaced around the loop. Branching out 20 from the loop are outfeed chutes or the like for receiving packages from the carriers. When a particular carrier holding a particular package to be sorted reaches a selected outfeed chute, an actuator tilts the tray to dump the package into the outfeed chute. Another example 25 of a typical package sorting conveyor is disclosed in International PCT Application Number PCT/DK90/00047 of Kosan Crisplant A/S, now U.S. Patent No. 5,664,660.

30 One significant disadvantage of conventionally designed package sorting conveyors is that conventional conveyor carriers laterally tilt only on a horizontal axis parallel to the direction of conveyor travel. While this accomplishes the objective of dumping the package from the carrier into an outfeed chute or the like, the package is often roughly tumbled or rolled, sometimes 35 damaging the package's contents. One reason for this is that the packages typically are unloaded from the carrier

while still traveling forward at the same speed as the conveyor. Thus, packages tend to slam into a forward retaining wall of the outfeed chute before sliding down the chute. Another problem with conventional laterally 5 tilting conveyors is that because the packages are moving forward at full speed when they are unloaded into the outfeed chute, the outfeed chute must be relatively wide so that packages do not miss the chute and fall off the conveyor past the chute. This often unnecessarily 10 increases the overall size of the conveyor system.

U.S. Patent No. 4,744,454 and an improvement thereto, U.S. Patent No. 5,086,905, both to Pölling, disclose previous attempts to remedy this problem of rough handling by conventional laterally tilting conveyor 15 carriers. Both of these patents to Pölling disclose a conveyor element for a package conveyor that includes a tilting carrier tray mounted to be rotatable about two swivel axes. A first swivel shaft extends obliquely downward from the underside of the carrying tray and is 20 in turn connected at an angle to the end of a second swivel shaft extending obliquely upwards from a base support part of the conveyor element. Together, the two swivel shafts form a "V" that points in the direction of conveyor travel. Both of the swivel shafts lie in the 25 vertical plane of symmetry of the conveyor element when the carrier tray is disposed in its upright position.

Because the carrier tray of Pölling rotates about two oblique axes, the carrier tray can be tilted not only lateral on a horizontal axis, but is moved through a 30 geometrically complex spatial reorientation during package discharge. This allows for more gentle placement of a package on an outfeed chute than can be accomplished using conventional conveyor trays that laterally tip on only a horizontal axis. The Pölling conveyor element 35 more gently handles the packages by imparting some degree of rearward velocity to the packages as they are

discharged, which, when added to the forward velocity of the conveyor system, results in the packages' forward velocity during discharge being less than that of the conveyor system itself.

5        However, the conveyor elements of both of Pölling's patents are unduly complicated and intolerant of manufacturing discrepancies. In fact, the second Pölling conveyor element (U.S. Patent No. 5,086,905) was invented in an attempt to simplify the original design disclosed  
10      in the first Pölling patent (U.S. Patent No. 4,744,454), which had proved to be too expensive and complicated to manufacture efficiently. As a result of this complexity and cost, the Pölling devices have not enjoyed significant commercial acceptance and success.

15      One solution to these problems is shown in U.S. Patent No. 5,836,436, issued November 17, 1998 and co-owned by the assignee of the present invention, which is hereby incorporated by reference in its entirety. One feature of this reference is the use of a pull-down  
20      design for tilting the improve trays.

25      Another example of a sorter conveyor using a pull-down design for tilting its trays is shown in U.S. Patent No. 5,664,660, issued to Prydtz. The '660 patent is directed to a sorter conveyor having laterally tilttable transport trays, instead of a conventional transport chain driven by a driving station, in which a driving wheel or worm cooperates with the chain links, these being advanced arranged with guiding rails along a small mutual spacing and carrying both the transport trays and  
30      the tilt mechanisms associated therewith, which conventional arrangement causes considerable problems with respect to tolerances for both the longitudinal pitch of the chain links and the mounting of the guiding rails. The invention includes carts that are advanced  
35      along mutually widely spaced guiding rails, whereby the tolerance demands on the latter are reduced considerably.

Also, the carts are advanced by way of stationary linear motors, which, supposedly, renders any tolerance demands on the longitudinal pitch of the tray units entirely superfluous. Also the tilting mechanisms may be given a  
5 very simple design according to the patent. However, it has been discovered that there are operational problems associated with this type of design, especially the operation of its linear motors and tilting mechanism.

10 While the design shown in U.S. Patent No. 5,836,436  
148-370.03 overcomes some of the problems associated with the prior art designs, some problems have begun to surface over time as the units have been operated. One of these problems is when there is a mis-tip which causes "cascading errors."

15 "Cascading errors" were first discovered when audits at the end of the chute indicated there were more errors occurring than were predicted by errors indicating by tray verification. Normally, when a tray is to tip to the right immediately before the tray is being  
20 straightened, a series of photocells determines if the right hand arm is in the "low" or "tipped" position, or the "up" or "latched" position. If the controls said that the arm should be tipped and the verifier says that the arm is tipped then it was assumed that the product went down the correct chute. However, in certain cases, tray verification would predict five errors but chute audits would indicate 35 errors. This previously unknown effect is referred to in this application as "cascade errors."

25 30 Most pull-down tilting mechanisms are actuated by spring when the pivot switch is released by an energizing solenoid. In other words, the pivot switch is spring-biased in the "out" position but held in the retained position by the solenoid.

35 When the computer provides a pulse, the solenoid plunger retracts, enabling the pivot switch to spring

into the "out" position. The wheel strikes the pivot switch in front of the pivot point and the pivot switch unlatches the carriage and then as the wheel strikes the tail of the pivot switch, it pushes the pivot switch back 5 to the home position and the spring on the solenoid plunger pushes the plunger into a detent capturing the pivot switch in the home position. The computer initiates the unlatch but it is the action of the wheel on the tail that normally relatches it.

10 If the solenoid does not return to capture the pivot switch before the wheel leaves the pivot switch's tail or a wheel is missing or broken, this will allow the pivot switch to move away from its intended home position back into the engagement position. The next tilt module that 15 is not in the down position will then strike the pivot switch, tilt, and reset the pivot switch. If the pivot switch relatches properly this time, then that particular pivot switch will cause no more errors. If the pivot switch does not relatch it can again go into the engaged 20 position and cause additional problems.

The cascade effect, though, comes from the first carriage that was tipped incorrectly, for if it were assigned a tilt position further downstream, when that carriage (which has been tilted incorrectly) gets in 25 position to unload, the pivot switch at the proper destination chute will move into the engagement position.

But because that arm has been incorrectly tipped upstream, no action will take place and the pivot switch will stay in the out position until the next untipped 30 carriage arrives. That carriage will then be tipped at the wrong destination but should cause that pivot switch to relatch. If that particular tray was assigned a chute destination further downstream, when it arrives at its proper destination, the pivot switch will move into the 35 engagement position, but again cannot engage because the tilt module is already in the low position, the tilt

module will pass by and will not relatch the pivot switch. This pivot switch will then stay in the out position capturing the wheel of the next tilt module that is not tipped. This error will then continue to cascade 5 downstream until eventually the error will pass the last destination and the system should heal itself.

However, there are some conditions that can exist that cause the error not to heal itself but continue to cause problems. An example would be if a particular tilt 10 module were missing a wheel; that tilt module could then be loaded and when it gets to its destination, the pivot switch will go out to engage the wheel but with no wheel the module will not tip. The pivot switch will then catch the next available tray beginning the cascade 15 problem. This will continue to repeat itself and will occur and start cascade error any time the tray with the missing wheel is assigned a destination.

One attempted solution to this problem is to use the tip verification switch to shut the sorter down if the 20 pivot switch does not return to the "home" position within a given time period. However, with a large sorter this requires a maintenance man to then check the pivot switch to see if it should be reset and whether a wheel 25 is missing. In the meantime, everything just sits on the sorter. For time critical applications, such as airline baggage sorting, this delay may be unacceptable.

One solution to these problems is shown in U.S. Patent No. 6,009,992, issued January 4, 2000 and also 30 owned by the assignee of the present invention, which is hereby incorporated by reference in its entirety. One feature of this reference is the use of a powered up and powered down bi-directional pivot switch.

However, most of these designs are based around linear induction motors (LIMs) which are well accepted 35 today due to their quietness and low maintenance. Unfortunately, for all their advantages LIMs are not very

energy efficient. For example, pairs of LIMs, spaced at 80 feet intervals and operated at 480 volts, draws about 15 amps. This is about 90 watts per foot of sorter for about 70 pounds of thrust. To the contrary, prior art 5 chain drives would draw about 15 watts per foot of sorter for about 1500 pounds of thrust. Thus, the modern LIM drives, for all their other advantages, are energy hogs.

However, prior art, mechanical chain drives are just too noisy and high maintenance for today's market.

10 Thus, there remains a need for a new and improved sorting conveyor that is substantially as energy efficient as conventional chain drives while, at the same time, is mechanically as quiet and maintenance-free as the modern LIM drives.

15 **Summary of the Invention**

The present invention is directed to an improved sorting conveyor for transporting objects and unloading objects at one or more unloading stations adjacent the conveyor. Generally, the sorting conveyor includes: a 20 conveyor track; a train of the tilting conveyor carts connected end-to-end; and an opposed roller motor assembly for moving the conveyor carts on the conveyor track. In the preferred embodiment, the opposed roller motor assembly includes a pair of cantilevered, generally 25 cylindrical rollers on each side of an extended driven member attached to each conveyor cart.

Each of the tilting conveyor carts includes a trailer frame base. The trailer frame includes a roller structure for engaging the conveyor track, a driven 30 member responsive to the opposed roller motor assembly, and a hitch mechanism for connecting each tilting conveyor cart to an adjacent conveyor cart. The conveyor cart also includes a carrying tray for holding the objects and a tilttable support apparatus for supporting 35 the carrying tray above the trailer frame base and for allowing tilting of the carrying tray towards at least

one side of the conveyor to unload objects into unloading stations on at least one side of the conveyor.

The tilting mechanism tilts the carrying tray on the tilttable support apparatus to thereby unload objects into 5 one of the unloading stations adjacent the conveyor. The improved tilting mechanism includes a pair of actuating arms attached to the carrying tray on opposite sides of the tilttable support apparatus and a pull-down mechanism associated with each unloading station for selectively 10 pulling down one of the actuating arms so as to pull one side of the carrying tray downwardly into a tilted position.

In the present invention, each of the actuator arms includes a cam follower on a lower end of the actuator arm, and wherein the pull-down mechanism includes a 15 descending ramp adjacent the conveyor track, a laterally pivoting switch for directing the cam follower of a selected actuator arm into the descending ramp and a bi-directional, rotary actuator assembly connected to the 20 laterally pivoting switch.

In the preferred embodiment, the rotary actuator assembly includes an actuator arm having a first end and a second end, the pivot switch being connected to the first end of the actuator arm; and a bi-directional 25 actuator attached to the actuator arm second end, whereby the rotary actuator assembly is operable to rotate the laterally pivoting switch to engage the cam follower and direct the cam follower of a selected actuator arm into the descending ramp and for closing the laterally 30 pivoting switch after capture of the cam follower.

The opposed roller motor assembly preferably includes a pair of electric motors and a support frame attached to the conveyor track for supporting the motors.

At least one pair of cantilevered, drive rollers are 35 connected to each of the respective motors and adjacent to each of the surfaces of an extended fin driven member

attached to each of the carts. Each drive roller offsets the mechanical load of the other drive roller.

Accordingly, one aspect of the present invention is to provide a sorting conveyor for transporting objects and unloading objects at one or more unloading stations adjacent the conveyor. The sorting conveyor includes: a conveyor track; a train of conveyor carts connected end-to-end; and an opposed roller motor assembly for moving the conveyor carts on the conveyor track.

Another aspect of the present invention is to provide an opposed roller motor assembly for a sorting conveyor having a train of conveyor carts connected end-to-end for transporting objects and unloading objects at one or more unloading stations adjacent the conveyor.

The opposed roller motor assembly includes: a motor; a support frame attached to the conveyor track for supporting the motor; at least one cantilevered, drive roller connected to the motor and adjacent to one surface of an extended fin driven member attached to each of the carts; and an opposing surface adjacent to the other surface of the extended fin driven member for off-setting the mechanical load of the drive roller.

Still another aspect of the present invention is to provide a sorting conveyor for transporting objects and unloading objects at one or more unloading stations adjacent the conveyor. The sorting conveyor includes: a conveyor track; a train of conveyor carts connected end-to-end, each of the conveyor carts including: a trailer frame base, including: a roller structure for engaging the conveyor track, an extended fin driven member, and a hitch mechanism for connecting each conveyor cart to an adjacent conveyor cart; a carrying tray for holding the objects; and a tiltable support apparatus for supporting the carrying tray above the trailer frame base and for allowing tilting of the carrying tray towards at least one side of the conveyor to unload objects into unloading

stations on at least one side of the conveyor; and an opposed roller motor assembly for moving the conveyor carts on the conveyor track, the roller motor assembly including: a motor; a support frame attached to the conveyor track for supporting the motor; at least one cantilevered, drive roller connected to the motor and adjacent to one surface of the extended fin driven member; and an opposing surface adjacent to the other surface of the extended fin driven member for off-setting the mechanical load of the drive roller.

These and other aspects of the present invention will become apparent to those skilled in the art after a reading of the following description of the preferred embodiment when considered with the drawings.

**15 Brief Description of the Drawings**

Figure 1 is a schematic depiction of a package sorting conveyor constructed according to the present invention;

Figure 2 is front, elevational view of a single tilting conveyor cart of the package sorting conveyor and the opposed roller motor assembly of the conveyor;

Figure 3 depicts a train of trailer frame structures of the conveyor carts, as seen from the top, but with the tilttable support apparatuses and the carrying trays of the conveyor carts removed for clarity;

Figure 3A depicts a top view of an axle caster that holds a cam follower on one of the conveyor carts;

Figure 3B is a cross-sectional view of the axle caster and cam follower of Figure 3A, taken along lines 3B-3B;

Figure 4 is an elevational side view of one of the tilting conveyor carts of the present invention;

Figure 5 is a sectional side view of a tilting conveyor cart, taken along lines 5-5 of Figure 2, which shows the tilttable support apparatus and the angled pivot structure of the tilting conveyor cart of the invention;

Figure 5A is a geometric depiction of the conveyor cart pivot axis and conveyor line of travel as they relate to three-dimensional X,Y,Z spatial coordinates;

5 Figure 6 is a top view of the train of carts of the package sorting conveyor of the present invention;

Figure 6A shows the train of carts of Figure 6, but with one of the carts in its tilted position and unloading a package onto an unloading station beside the sorting conveyor track;

10 Figure 7 is a rear view of the tilting conveyor cart taken along lines 7-7 of Figure 4 with the track rails and the roller structure omitted for clarity, which shows the conveyor cart in its upright, horizontal position;

15 Figure 7A shows the tilting conveyor cart of Figure 7 in its tilted position;

Figure 8 is a side elevational view of the pull-down mechanism of the invention with its switch in an open position as it captures a passing cam follower on a conveyor cart actuating arm;

20 Figure 8A is another side view of the pull-down mechanism, except with the cam follower traveling through the descending ramp and the switch in its closed position;

25 Figure 9 is a top view of the pull-down mechanism with the switch in its open position, capturing a passing cam follower;

30 Figure 9A is another top view of the pull-down mechanism, except with the cam follower traveling through the descending ramp and the switch in its closed position;

Figure 10 is a top view of the push-up mechanism;

Figure 10A is a side view of the push-up mechanism;

Figure 11 is a cross sectional view showing the bi-directional actuator connected to the pivot switch;

35 Figure 12 is a top view of the opposed motor roller assembly, with the track omitted for clarity;

Figure 13 is a downstream, rear view of the opposed motor roller assembly, with the track omitted for clarity; and

5 Figure 14 is a bottom view of the opposed motor roller assembly.

**Description of the Preferred Embodiments**

In the following description, like reference characters designate like or corresponding parts throughout the several views. Also in the following 10 description, it is to be understood that such terms as "forward", "rearward", "left", "right", "upwardly", "downwardly", and the like are words of convenience and are not to be construed as limiting terms.

Referring now to the drawings in general and Figure 15 1 in particular, it will be understood that the illustrations are for the purpose of describing a preferred embodiment of the invention and are not intended to limit the invention thereto. As seen in Figure 1, a sorting conveyor, generally designated 10, is shown 20 constructed according to the present invention for transporting and sorting packages 11 or other objects. The sorting conveyor 10 comprises a train of individual carts 20, connected end to end, which preferably form an endless loop around a closed-circuit conveyor track 12. 25 Alternately, the conveyor carts 20 of the invention could be used singly or as part of a finite train.

The package sorting conveyor 10 generally includes 30 four major sub-assemblies: a conveyor track 12; an opposed roller motor assembly <sup>210</sup>~~70~~; the train of tilting conveyor carts 20, which are moved along the conveyor track 12 by the opposed roller motor assembly 70; and a tilting mechanism 80 for tilting the conveyor carts 20 to discharge packages 11 therefrom. Typically, any number 35 of unloading stations or outfeed chutes 18, which are adjacent the package sorting conveyor 10 on one or both sides thereof, receive the packages 11 discharged from

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the sorting conveyor 10 and carry the packages to waiting storage bins, trucks, etc. Packages may be manually placed on the conveyor carts 20 or may be delivered to the sorting conveyor 10 via infeed chutes 17 or the like.

5        The conveyor track 12 includes two parallel rails 14 and may be built to conform to the layout of any warehouse, shipping center, distribution center, or the like. Best seen as resembling the track of a roller coaster, the conveyor track 12 may be substantially 10 horizontal or may ascend and descend. The conveyor track rails 14 may lie in the same horizontal plane, or one may be higher than the other, such as would be the case in a banked curve in the track 12. Banked curves are greatly 15 advantageous because they allow the conveyor carts 20 to move around a curved conveyor track 12 at a much greater speed without spilling packages 11 than on a flat track. Preferably, the rails 14 are generally tubular, again 20 similar to a roller coaster, and are supported by rail support members 16 only on the outwardly facing edges of the rails. The rails 14 may be round or rectangular in cross-section. Rectangular cross-section is preferred 25 since it has been found that round rails cause the cam followers to wear somewhat in their center because the load is not as well distributed as when rectangular rails are utilized.

RPS        The opposed roller motor assembly 210 of the sorter conveyor 10, which is shown in Figure 2, is preferably a pair of opposed drive roller assemblies <sup>214, 214'</sup> ~~14, 14'~~ which is discussed in more detail in Figures 12 and 13. A driven fin 36, which is attached to the bottom of each conveyor cart 20, hangs between the two drive roller assemblies <sup>214, 214'</sup> ~~14, 14'~~.

RPS        Composed of semi-rigid, high coefficient aluminum or other conductive metal, the vertical fin 36 preferably 35 has swept-back front 36a and rear 36b edges, as shown in Figure 4, giving the fin 36 a generally parallelogram

shape to reduce damage in the event the fin would contact a structure and to distribute the air gap over the length of the drive rollers to reduce noise and maintain more constant thrust. Specifically, because the gap is angled 5 with respect to the roller, the roller does not hit the gap like a pot hole which is large enough for both wheels to hit at the same time.

Vertically orienting the fin 36 and the opposed roller assembly 210 also reduces problems with 10 maintaining proper spacing between the fin 36 and the drive rollers, because gravity ceases to be a factor as the weight of the live load varies. This results in the fin 36 being easily maintained equidistant between the two drive rollers.

15 The opposed roller motor assembly 210 ordinarily moves the train of conveyor carts 20 in one direction of travel; however, it can also be reversed if necessary to to slow or stop the conveyor.

Now turning to the train of tilting conveyor carts 20, each cart 20 includes three major sub-assemblies, 20 shown best in Figure 2: a trailer frame structure 22, a generally horizontally disposed carrying tray 40 for holding the packages 11, and a tiltable support apparatus 50 for supporting the carrying tray 40 above the trailer frame structure 22 and for allowing tilting of the carrying tray 40 towards either side of the sorting conveyor 10 to unload a package into one of the unloading stations. Each cart 20 is built around a base trailer frame structure 22 to which other components of each cart 25 30 are mounted. As shown in Figure 3, the trailer frame structure 22 includes a longitudinal base member 24 that extends in the rearward direction of conveyor travel 64 between the two parallel rails 14. Preferably, the base member 24 is substantially equidistant from each rail 14.

35 A roller structure 26 for riding on the conveyor track 12 is mounted on a front end of the base member 24

and includes two laterally extending cam follower mechanisms 27, one for each rail 14. The reason for the outboard placement of the rail supports 16 and the tubular shape of the rails 14 becomes apparent upon  
5 examining the cam follower mechanisms 27. Each cam follower mechanism 27 includes three cam followers: an upper cam follower 30a for riding on the top edge of the rail 14, a middle cam follower 30b for riding on an inside edge of the rail 14, and a lower cam follower 30c  
10 for riding on the bottom edge of the rail 14. With this configuration, it is almost impossible for a cart 20 to jump the track 12, because a wheel is provided for each directional force (sideways, upward, and downward) that a cart 20 may encounter when traveling along the track 12.

15 Preferably, each cam follower 30a,b,c is constructed of a somewhat resilient material such as polyurethane to provide for smooth, quiet, relatively vibration-free operation of the sorter conveyor 10.

20 Referring now especially to Figures 3A and 3B, the structure of each cam follower mechanism 27 that holds the top wheel 30a is shown in greater detail. Each top cam follower 30a is retained by an axle caster 28 that is preferably formed from extruded aluminum or the like. The axle caster 28 includes two forks 28a and 28b, one on  
25 each side of the wheel 30a, and a bearing bore 28c disposed at the juncture of the two forks 28a,b, which has an opening 28d on one side so that the bearing bore 28c communicates with the space between the forks 28a,b.

30 A pair of flange bearings 29 seated in the bearing bore 28c are disposed around an axle shaft 27a extending from the roller structure 26. Preferably formed of "oilite" or other friction-reducing material, each flange bearing 29 has the form of a top-hat bushing and includes a center hole 29a through which passes the axle shaft 27a.

35 The cam follower 30a is held in place between the two forks 28a,b by a bolt 31 and nut 31a. Preferably, the

cam follower 30a includes a bearing structure 30d disposed around the bolt 31, which serves as an axle running through the center of the wheel 30a.

The axle caster shown in Figures 3A and 3B represents an improvement over existing axle casters that hold cam followers. Due to wear, axle casters inevitably tend to become loose and allow the cam followers to chatter back and forth, which would inhibit smooth, quiet, vibration-free operation of a sorting conveyor. However, previously designed axle casters typically have a bearing around the axle shaft that must be pressed out when worn and replaced with a new bearing that must be pressed in. This requires a press in addition to more time and expense than is desirable in a large sorting conveyor system.

The axle caster 28 of the present invention solves this problem by providing that the flange bearings 29 can easily be slid into place by hand into the bearing bore 28c without using a press. Then, to immovably secure the flange bearings 29 inside the bearing bore 28c, the forks 28a,b are slightly flexed inwardly towards each other as the nut 31a is tightened onto the bolt 31 to hold the wheel 30a in place. The forks 28a,b of the axle caster 28 are therefore formed minutely wider apart than would be necessary to merely hold the wheel 30a. When the forks 28a,b are flexed inwardly towards each other by tightening the nut 31a on the bolt 31, the opening 28d of the bearing bore 28c is closed somewhat and the bearing bore 28c is itself slightly distorted, securely retaining the flange bearings 29 therein. The flange bearings 29 themselves are, however, not significantly distorted and are free to swivel back and forth on the axle shaft 27a.

Therefore, the flange bearings 29 can easily and immediately be replaced on-site when worn, eliminating much down-time that would be required if conventionally

designed axle casters were used in the conveyor cart 20 of the present invention.

Adjacent carts 20 in the train are connected together using hitch mechanisms 32. Each hitch mechanism 5 32 is shown in Figures 3 and 4 as including a front hitch 32a mounted on the front end of the base member 24 in front of the roller structure 26 and a rear hitch 32b mounted on the rear end of the base member. In the embodiment disclosed, each hitch 32a,b has a vertical 10 throughbore, through which a hitch pin connector 32c is inserted. Preferably, the hitch mechanisms 32 are configured so that the front hitch 32a on a rearward cart is disposed overtop of the rear hitch 32b on a forward cart. In the alternative, the hitch mechanisms 32 may 15 comprise a poly-directional spherical ball joint mechanism similar in structure to an automotive trailer hitch. In either case, friction between hitch mechanism components is preferably reduced by, for example, lining the hitch components with TEFLON or other relatively 20 friction-free material.

To prevent adjacent conveyor carts 20 from separating should the hitch mechanism 32 accidentally break or become uncoupled, an auxiliary cart connector 34 is preferably connected between the trailer frame 25 structures 22 of adjacent carts 20. In the preferred embodiment, the auxiliary cart connector 34 is a metal cable or lanyard, although other high-tensile strength materials could be used. In the embodiment depicted, the auxiliary cart connector 34 is an approximately 3/16th 30 inch thick metal cable connected to adjacent trailer frame structures 22 with metal mounting connectors 34a.

The primary reason that metal is the preferred material for the auxiliary cart connector 34, besides its strength, is so that the auxiliary cart connector 34 will 35 also serve as a continuous electrical connector between adjacent carts 20. Electrical continuity between carts

20 is important because of static electricity build-up while the carts 20 are traveling around the conveyor track 12. However, because the cam followers 30a,b,c are preferably formed of polyurethane (an electrical 5 insulator) and because the components of the hitch mechanism 32 are preferably coated with TEFLON (also an electrical insulator), electrical continuity between adjacent carts 20 would not otherwise be effectively achieved. By electrically connecting the carts 20, 10 static charges can be bled off from the train, which is important for safety and operational considerations. Thus, the auxiliary cart connector 34 serves two important purposes: first, it physically attaches two adjacent conveyor carts 20 and prevents them from 15 becoming completely separated should the hitch mechanism 32 fail; second, it enables electrical continuity among all of the conveyor carts 20 in the train.

The configuration of the conveyor cart 20 of the present invention, with its forwardly mounted roller structure 26, particularly structured hitch mechanism 32, and swept-back fin 36 is a significant improvement over 20 previously designed conveyor carts. In conventional conveyor carts, the roller structures are typically mounted at the rear end of the trailer frame and the rear 25 hitch is disposed overtop of the forward hitch. When a hitch mechanism breaks or becomes accidentally uncoupled with this old configuration, the result is that the forward end of the trailer frame drops below the conveyor track and is pushed over underlying structures or the 30 floor. As this uncoupled cart contacts the surrounding permanent structures, the force exerted by the mass and acceleration of the carts leads to inevitable damage to the sorter carts, the conveyor track, and the surrounding structure. This occurrence is similar to a railroad 35 train becoming derailed from the tracks causing massive

damage to the individual carts, the railroad track and any surrounding structure that the train contacts.

With the present design, even without the auxiliary connector cable 34, only the rear end of the trailer frame structure 22 will drop below the conveyor track 12 upon accidental disengagement of the hitches 32a,b or upon breakage of the hitch mechanism 32. Therefore, instead of the front end 36a of the driven fin 36 digging into the floor sides or underlying structures below the conveyor, as is the case with prior art conveyors, the driven fin 36 will simply be dragged with relatively minimal damage should one of the hitches 32 break or become accidentally uncoupled. If an auxiliary connector cable 34 is attached between two adjacent carts 20 that break apart, the connector cable 34 will limit the distance that the rear end of the trailer frame structure 22 will drop, further limiting damage.

Mounted atop the trailer frame structure 22 of each conveyor cart 20 is the tiltable support apparatus 50, which supports the carrying tray 40 thereabove. As can best be seen in Figure 5, the tiltable support apparatus 50 generally includes three components: an upper support structure 52 joined to a bottom surface of the carrying tray 40, a lower support structure 58 centrally mounted atop the longitudinal base member 24, and an angled pivot structure 60 pivotally connecting the lower support structure 58 to the upper support structure 52 along a pivot axis 62.

In turn, the upper support structure 52 includes a front support member 54 and a back support member 56. The lower support structure 58 is preferably generally planar, lying in the vertical plane parallel to the conveyor line of travel 64, and includes an angled upper edge 58a. The pivot structure 60 preferably includes an axle 68 that runs either through or along the upper edge 58a of the lower support structure 58 and is connected to

the front and back support members, 56, 58, respectively.

Preferably, the axle 68 runs through lower regions of the front and back support members 56, 58. As can be seen, the front support member 54 depends farther down from the carrying tray 40 than the back support member 56. While the lower support structure 58 is stationarily fixed to the trailer frame 22, the axle 68 allows the upper support structure 52 to pivot along the pivot axis 62 of the pivot structure 60.

10 In an alternate embodiment of the tiltable support apparatus (not shown), the upper support structure 52 could also comprise, like the lower support structure 58, a generally planar member that lies in the vertical plane parallel to the conveyor line of travel 64. In this 15 case, the angled pivot structure 60 could take on the form of a hinge structure joining together the two generally planar support structures 52, 58.

20 The pivot axis 62 lies in a vertical plane parallel to the conveyor line of travel, which is shown in the drawings as horizontal line 64. However, unlike conventional sorter conveyor tilting carts, the pivot axis 62 of the conveyor cart 20 of the invention is disposed at an angle  $\theta$  to the conveyor line of travel 64 so as to impart two axial components to the tilting of 25 the carrying tray 40. Preferably, the pivot axis 62 is angled downwardly at an angle of approximately 20 to 45 degrees below horizontal in a forward direction. In the embodiment disclosed, the pivot axis 62 is angled downwardly 30 degrees. As can be seen in Figure 5, the 30 pivot axis 62 preferably intersects a plane occupied by the carrying tray 40 rearward of the center of the tray 40.

35 By disposing the pivot axis 62 at a downwardly directed angle  $\theta$  instead of parallel to the conveyor line of travel 64, two axial components are imparted to the tilting motion of the carrying tray 40. The first axial

component of the tray's tilting motion is lateral tipping on a horizontal axis parallel to the conveyor line of travel 64. The second axial component of the tray's tilting motion is rotating around a vertical axis 66 perpendicular to the conveyor line of travel. Thus, while the tray only tilts along a single, angled pivot axis 62, the overall motion of the tray 40 as it tilts includes two axial components.

The tilting motion of the tray may also be described using three-dimensional X, Y, and Z-axis spatial coordinates, as shown in Figure 5A, wherein the Y-axis is parallel to the conveyor line of travel 64, the X-axis extends horizontally perpendicular to the line of travel 64, and the Z-axis extends vertically perpendicular to the line of travel 64. In the present invention, tilting of the tray 40 includes a Y-axis and a Z-axis component, for as shown in Figure 5A the pivot axis 62 intersects the Y and Z axes. Specifically and for illustrative purposes only, using the preferred 37.5 degree downward angle  $\theta$  of the pivot axis 62, it can be appreciated that the ratio of Y-axis motion to Z-axis motion is 60 : 30. In other words, with a 30 degree angle  $\theta$ , the tray 40 laterally tips somewhat farther than it rotates. If the angle  $\theta$  of the pivot axis 62 is increased to 45 degrees below horizontal, then the tray will tilt and rotate equally.

As shown in Figures 6 and 6A, one effect of this two-axis tilting of the carrying tray 40 is that a side 44b of the tray that is tilted downwardly also rotates rearwardly relative to the cart 20, as shown in Figure 6A by line 46a. Side 44d of the tray, which is tilted upwardly, rotates forwardly relative to the cart 20, as shown in Figure 6A by line 46b. In the preferred embodiment, in which the pivot axis 62 intersects the plane occupied by the tray 40 rear-of-center, the front

5 side 44a of the tray 40 rotates a greater distance around the vertical axis 66 than the back side 44c of the tray 40, upon tilting of the tray 40. As shown in Figure 6A, the bisecting center line of the tray 40 rotates farther  
10 at its forward end from the horizontal line of travel 64 than at its rearward end. Thus, front side rotation line 48a follows a longer arc than back side rotation line 48b. By rearwardly rotating whichever side of the tray 40 is being tilted downwardly, some rearward velocity is  
15 imparted to packages 11 as they are being discharged from the cart 20 of the invention into an unloading station 18. Thus, packages are discharged at a lower velocity relative to the unloading station than the velocity of the train of conveyor carts as a whole. This enables the  
20 packages to be discharged into a narrower chute than could be accomplished using a conventional conveyor cart. Additionally, because the packages are slowed down somewhat as they are discharged, there is less potential for damage to occur.

25 As can be seen in the drawings, the tray 40 may also include upwardly angled lateral wings 42 to help prevent packages 11 from accidentally falling off the tray 40. These wings 42 also decrease the angle of the slope created when the tray 40 is tilted, which helps with gentle handling of the packages 11 as they are discharged from the cart 20.

30 When a carrying tray 40 reaches a particular destination unloading station 18, the tilting mechanism 80 tilts the carrying tray 40 to cause a package 11 carried thereon to be discharged into the unloading station 18. The tilting mechanism 80 generally includes components mounted on each conveyor cart 20 and components associated with each unloading station 18. First is a pair of actuating arms 82 attached beneath each cart's carrying tray 40 on opposite lateral sides  
35 thereof, one actuating arm 82 on each side of the cart's

tiltable support apparatus 50. Second is a pull-down mechanism 90 immediately upstream from each unloading station 18. The pull-down mechanism 90, when activated, selectively pulls down one of the actuating arms 82 and thereby pulls the respective side of the tray 40 downwardly and rearwardly into the biaxially tilted position described above. Third is a push-up mechanism 110 downstream of the unloading station 18, which pushes up the actuating arm 82 pulled down by the pull-down mechanism 90 and thereby reorients the tray 40 into its normal, upright position. Fourth is a locking structure 120, which locks the carrying tray 40 in the tilted position upon pulling down of one of the actuating arms 82, and which also locks the carrying tray 40 in its normal, upright position upon pushing up of that actuating arm 82.

Referring now to Figures 7 and 7A, each actuating arm 82 is pivotally attached to the underside of one side of the carrying tray and is preferably connected to the front and back support members, 54 and 56 respectively, of the upper support structure 52. In the embodiment shown, the actuating arm 82 is attached to the front and back support members by an angled pivot hinge axle 84 that runs through both support members 54, 56 and through the upper end of the actuating arm 82. The actuating arm 82 therefore pivots on a pivot axis 86 that is preferably parallel to the pivot axis 62 of the tiltable support apparatus 50, as shown in Figure 5. As can be seen from an examination of the drawings, the actuating arms 82 and their respective pivot axes 86 remain substantially in a vertical plane parallel to the conveyor line of travel 64 when stationary and when being pulled down or pushed up.

Each actuating arm 82 also includes a cam follower 88, which engages the pull-down and push-up mechanisms 90, 110, as will be described below. The cam follower 88 is preferably mounted on the lower end of the actuating

5 arm 82 on an outer surface 82a thereof. It is conceivable, however, that the cam follower 88 could be replaced with a friction reducing slide block or other protrusion for engagement by the pull-down and push-up mechanisms 90, 110.

10 Seen in detail in Figures 8, 8A, 9, and 9A, a pull-down mechanism 90 is associated with each unloading station 18 and is located beneath the rail 14 running closest to the unloading station 18 on the upstream side thereof, as indicated in Figure 6A. The pull-down mechanism 90 includes a descending ramp 92 and a laterally pivoting switch 94 that, when actuated, pivots open and directs the cam follower 88 of a passing actuating arm 82 into the descending ramp 92. As can be 15 seen in the drawings, when the switch 94 is not actuated, the switch is in a closed position parallel to the ramp 92, and the cam follower 88 is free to bypass the switch and the descending ramp 92. However, when a particular package 11 arrives at its destination unloading station 20 18, the switch 94 is automatically actuated so that it pivots open into the path of the passing cam follower 88, capturing the cam follower 88. The cam follower 88 then rolls through the switch 94, causing the actuating arm 82 to pivot outwardly somewhat, and into the descending ramp 25 92. As the cam follower 88 rolls through the switch 94, the cam follower 88 engages a closure flange 104 and enters the descending ramp 92. Next, the descending ramp 92 forces the cam follower 88 and the associated actuating arm 82 downwardly so as to pull down one side 30 of the tray 40, thereby discharging the package from the tray 40 into the unloading station 18 adjacent the pull-down mechanism 90.

35 A computer controller (not shown) is used to track all packages 11 moving on the conveyor 10 and to automatically actuate a switch 94 at the appropriate time when a particular package 11 reaches its destination

unloading station or outfeed chute 18. The computer is also connected to the opposed roller motor assembly 210 to control the movement of the conveyor train and maintain a desirable rate of speed.

5 The pivot switch 94 is attached to a bi-directional actuator 150 as shown in Figures 8 and 8A. The bi-directional actuator is mounted below the pivot switch 94 away from the moving cam followers. As shown in Figure 11, the bi-directional actuator 150 includes a coaxial 10 arm 152 extending from an actuator motor 154 and connected to the interior of the pivot switch 94.

15 The actuator motor 154 rotates the coaxial arm 152 and the attached pivot switch 94 between the open position to capture the cam follower 88 and the closed position to allow the cam follower to bypass the unloading station. Power and communication means with the conveyor system is supplied to the actuator motor 154 via a cord 160. To rotate the coaxial arm to an open position, power is continuously applied to the motor to 20 maintain the pivot switch in the open position. When power is turned off, a coil spring positioned inside the actuator motor 154 biases the arm causing the pivot switch to rotate to the closed position. This combination of powered on and powered off enables the 25 pivot switch to be controlled independently of the movement of the cam followers. In one embodiment, the actuator motor is a 500 Model 40R10102-10-11 rotary solenoid actuators ("the model 40R actuators") from Ram Manufacturing Company, Inc. The actuator motor 154 is 30 mounted within a heat sink 172.

35 As best seen in Figure 11, an outer clevis 162 surrounds the actuator arm 152 and is mounted between an upper bracket 164 and a lower bracket 166. The outer clevis 162 is mounted to a lower body 174 that is aligned substantially perpendicular to align with the lower bracket 166. Connector means such as screw or bolts

mount extend through the lower bracket 166 and lower body 174 to secure the bi-directional actuator to the tipping mechanism. The outer clevis 162 is sized larger than the actuator arm 152 such that as the arm rotates, the clevis 5 maintains a fixed position. A roll pin 170 extends through the actuator arm 152 and outer clevis 162 and into the interior of the pivot switch 94. The roll pin 170 is fixedly attached to the actuator arm 152 such that the rotation of the actuator arm moves the pin which 10 thereby moves the pivot switch through the open and closed positions. The roll pin extends through apertures within the outer clevis such that the pin has a free range of movement.

15 The outer clevis 162 and upper bracket 164 and lower bracket 166 protect the actuator arm 152 from stresses applied to the pivot switch 94. The outer clevis 162 allows for the pivot switch to pivot about the clevis, but prevents the pivot switch from moving in a linear direction which could damage the actuator arm.

20 In use, the actuator motor 154 is energized thereby rotating the actuator arm 152 causing the pivot switch to rotate to the open position. The next passing cam follower will be captured by the pivot switch and diverted into the unloading station path. After the cam 25 follower has been captured, power to the actuator motor 152 will be stopped causing the inner coil spring to bias the pivot switch in the closed position. However, while the cam follower is running along the length of the pivot switch, the force of the wheel will maintain the switch 30 in the open position. Once the cam follower has passed downstream of the pivot point, the pivot switch will rotate to a closed position by the biasing of the internal coil spring.

35 This arrangement provides for the pivot switch to be maintained in an open position for the shortest duration thereby allowing the speed of the sorter conveyor to be

increased over previous designs without the problem of the switch inadvertently remaining open and catching the next passing cam follower thereby starting the cascade effect. Powering down the pivot switch to the closed 5 position will also remove inadvertent captures such as when a cam follower is missing from the actuating arm or if the cam follower were to jump the pivot switch without entering the unloading station. Previously available 10 designs depended upon the cam followers passing along the pivot switch to rotate the pivot switch to the closed position.

After the carrying tray 40 has been tilted and a package carried thereon has been discharged into an unloading station 18, the carrying tray is reoriented 15 into its normal upright position by the push-up mechanism 110. Seen best in Figures 10 and 10A, a push-up mechanism 110 is associated with each unloading station 18 and is located beneath the track 12 adjacent the unloading station 18 on the downstream side thereof, as 20 indicated in Figure 6A. Each push-up mechanism 110 includes an ascending ramp 112 below the rail 14 adjacent the unloading station 18. The push-up mechanism 110 also includes a wedge-shaped frog 114 that engages the cam follower 88 on a pulled-down actuating arm 82 and directs 25 the cam follower 88 into the ascending ramp 112. The frog 114 is positioned low enough below the track 12 so that cam followers 88 will be engaged and directed into the ascending ramp 112 only if they have already been pulled down by the pull-down mechanism 90. As the cam 30 follower 88 is directed into the ascending ramp 112, the actuating arm 82 is pivoted outwardly somewhat so that the outside edge 123 of the locking flange 122 will disengage from the tilted position locking channel 127. To help pull the actuating arm 82 back into substantially 35 vertical alignment after the locking flange 122 has slid

over the slide surface 130, the top of the ascending ramp 112 includes an inwardly turned section 116.

Now turning to the locking structure 120 of the tilting mechanism 80, it can be seen best in Figures 7 5 and 7A that the locking structure 120 includes a pair of locking flanges 122, a pair of locking blocks 124 mounted one each to the actuating arms 82, and a biasing member 134 for biasing the actuating arms 82 inwardly into a locked position. Preferably, the locking flanges 122 10 laterally extend from both sides of the lower support structure 58 of the tilttable support apparatus 50, although they could also be mounted to the trailer frame structure 22. In the embodiment disclosed, the locking flanges 122 comprise generally planar steel plates having rollers 123 mounted to their outer edges 123. In an 15 alternate embodiment, the rollers 123 could be eliminated and the locking blocks 124 made of a low-friction material on which the roller-less outer edges of the locking flanges 122 could easily slide.

Each locking block 124 is mounted to an inner 20 surface 82a of the actuating arm 82 and includes two locking channels 126 and 134 separated by a cammed section 130 having a generally convex outer surface. The lower 126 of the two locking channels receives the roller 123 at the outer edge of the lateral locking flange 122 when the carrying tray 40 is in its upright position. The upper 134 of the two locking channels receives the roller 123 when the carrying tray 40 is in its tilted 25 position. As the tray 40 is tilted from one position to the other, the roller 123 rolls over the cammed section 130 interposed between the two locking channels 126, 134.

30 Preferably, the locking blocks 124 are made of a wear-resistant material such as plastic, although other materials could be used. The biasing member, which may 35 be a spring 134, pulls the actuating arms 82 inwardly so as to engage the locking structure 120 by seating the

locking flanges 122 in one of the locking channels 126, 134.

During tilting of the tray 40 by the pull-down mechanism 90, the actuating arm 82 being pulled down is pivoted outward slightly on the pivot axis 86 as the cam follower 88 is captured by the switch 94 and directed into the descending ramp 92. This outward pivoting of the actuating arm 82 causes the upright position locking channel 126 to disengage from the locking flange 122.

Then, as the cam follower 88 is pulled down by the descending ramp 92, the locking flange 122 rolls upwardly over the cammed section 130. Because of the curved, convex shape of the cammed section 130 of the locking block 124, the actuating arm 82 remains substantially vertical as it is pulled down. This helps prevent the cam follower 88 from slipping out of the descending ramp 92 of the pull-down mechanism 90. Eventually, the locking flange 122 is seated in the tilted position locking channel 134 as the wheel exits the descending ramp 92 and the tray 40 reaches its fully tilted position. The degree to which the tray 40 is tilted in the fully tilted position can vary depending on the configuration of the locking blocks 124 and the pull-down mechanism 90. However, in the embodiment disclosed, the tray 40 is tilted approximately 37.5 degrees from horizontal in the fully tilted position.

The biasing member 134 holds the tilted position locking channel 134 and the locking flange 122 together while the cart 20 is moving past the unloading station 18, stabilizing the tray 40 in the tilted position. Then, when the downwardly pulled actuating arm 82 reaches the push-up mechanism, the arm 82 is pivoted outwardly by the wedge-shaped frog 114 engaging the cam follower 88. This outward pivoting causes the locking flange 122 to disengage from the tilted position locking channel 134. As the cam follower 88 moves up the ascending ramp 112,

the locking flange rolls downwardly over the cammed section 130. As the inwardly turned top end 116 of the ascending ramp 112 pivots the actuating arm 82 back to its vertical orientation, the locking flange 122 seats in the upright position locking channel 126, where it is held in place through the action of the biasing member 134.

5 The actuating arm 82 on the opposite side of the conveyor cart 20, which is not being pulled down or  
10 pushed up at a particular unloading station 18, simply rises and falls with the side of the tray 40 to which it is attached. The locking flange 122 on this side of the cart 20 simply rolls over a flat section 132 of the locking block 124 below the upright position locking  
15 channel 126.

20 In an alternate embodiment (not shown) of the package sorting conveyor 10 of the invention, the conveyor cart 20 could include a tilttable support apparatus having a pivot axis that is not angled downwardly but that is generally parallel to the conveyor line of travel 64. In this case, the tilting motion of the carrying tray 40 would only have a single axial component - lateral tipping on a horizontal axis parallel to the conveyor line of travel 64. While package sorting conveyors having a single-axis lateral tipping motion  
25 have been designed in the past, they do not include the other inventive features of the present sorting conveyor 10 such as the vertically oriented opposed roller motor assembly 210, the hitch mechanism 32 and auxiliary cart connector 34, and the tilting mechanism 80 with its  
30 associated components. However, for many applications, a single axis tilttable cart will be sufficient.

35 Such single-axis conveyor carts would primarily be incorporated into the package sorting conveyor 10 of the present invention for use in sorting particularly large packages that must be carried by two or more adjacent

carrying carts 20. In this case, the trays of the adjacent carts could be simultaneously tilted as the carts reached an unloading station to discharge the package. This would also of course require an especially wide outfeed chute as well as a pull-down mechanism adjacent the unloading station for each cart to be simultaneously tilted.

The reason that single-axis conveyor carts are especially useful for sorting large packages is that it has been found that this double (or triple, etc.) unloading of particularly large packages using the two-axis carrying carts 20 of the present invention occasionally presents difficulties due to the carrying trays 40 not being in the same spatial plane when they are both in their fully tilted positions. Therefore, for double unloading, it is preferable to use the alternate, single-axis embodiment of the conveyor cart.

Several configurations of the package sorting conveyor 10 may be employed that utilize the alternate, single-axis conveyor carts for double unloading situations. A preferable configuration would comprise two adjacent single-axis carts for carrying a single large package. A second configuration would comprise a leading two-axis conveyor cart 20 and a trailing single-axis cart. A third configuration would comprise a leading single-axis conveyor cart and a trailing two-axis conveyor cart 20. As a whole, the package sorting conveyor 10 of the invention may include both two-axis conveyor carts 20 as well as single-axis conveyor carts interspersed among each other depending on a particular facility's conveying and sorting requirements.

As best shown in Figures 12 and 13, the preferred embodiment of the opposed motor roller assembly 210 of the present invention is comprised of a pair of support frames 212, 212', a pair of opposed drive roller assemblies 214, 214', and a pair of motor assemblies 216,

216'. The second drive roller assembly 214' provides the opposing surface 220 that exerts pressure in conjunction with the first drive roller 214 on the driven fin 36 of the cart 20.

5 Figure 12 shows a top view of the opposed motor roller assembly 210. The drive roller assemblies 214, 214' are mounted on respective pivot block assemblies 236, 236' and are connected to the shafts of motor assemblies 216, 216' with drive belts 262, 262'. Motor 10 assemblies 216, 216' are attached with bolts passing through slotted holes 218 in pivot block assemblies 236, 236' of adjustable sub-frame assemblies 224, 224'.

Pivot block assemblies 236, 236' are connected forward of the first shafts 226, 226' with a compression linkage 242. The first end 244 of compression linkage 242 is attached to pivot block assembly 236 and the second end 244' of compression linkage 242 is attached to pivot block assembly 236'.

20 Caster linkage 246 is an adjustable connector having two ends 250 and 252. First end 250 attaches to pivot block 236 and second end 252 attaches to base 222. Caster linkage 246 may alternatively be connected between pivot block 236 and base 222. The caster linkage 246 helps to ensure that the opposed motor roller assembly 25 210 remains fixed relative to the track structure.

Figure 13 shows that the pair of support frames 212 and base 222 are attached to the conveyor track 12 (see Figure 14 for track 12) and adjustable sub-frame assemblies 224, 224'. Adjustable sub-frame assemblies 30 224, 224' include pivot block assemblies 236, 236', first shafts 226, 226' that pass through pivot block assemblies 236, 236', and camber linkage 232, which is attached to the lower ends 234, 234' of first shafts 226, 226', as also best seen in Figure 14.

35 The first shafts 226, 226' are connected to base 222 with dowel pins 230, 230'. By adjusting the length of

camber linkage 232, the vertical alignment of the adjustable sub-frame assemblies 224, 224' may be adjusted. Adjustable sub-frame assemblies 224, 224' also include second shafts 238, 238' which pass through the 5 pivot block assemblies 236, 236' and roller assemblies 214, 214'.

The first shafts 226, 226' and second shafts 238, 238' have a plurality of Ringfedders™ locking rings 254, 254' on the ends nearest the pivot block assemblies 236, 10 236'. A sufficient number of Ringfedders™ locking rings 254, 254' are placed on each shaft prior to inserting it into the pivot block assembly to insure that, when compressed, the shaft is centered and secured.

The drive roller assemblies 214, 214' are generally 15 cylindrical and are made of aluminum or other light-weight alloy. They each have frictional surfaces 258, 258' at the end nearest the pivot block assemblies 236, 236' for engaging drive belts 262, 262' and outer elastomeric surfaces 256, 256' of about  $\frac{1}{4}$ " thickness on 20 most of the remainder of the surface. The frictional surface 258 is preferably a series of circumferential grooves that mate with the drive belt 262. The drive belt may be a poly v-belt, which is available from Browning Company in Florence, Kentucky. The outer 25 elastomeric surface is preferably polyurethane with a durometer value (Shore Type A) between 60 and 90. A suitable roller is an opposed drive roller is made of a polyurethane and is available from Urethane Innovators of New Bern, North Carolina. This selection of material was 30 made in order to balance durability and performance (i.e., resistance to slippage) of the rollers in this application.

Table 1, below shows the relative wear on a 1-5 scale of polyurethane compounds having different 35 durometer (Shore Type A) values compared with relative slippage. The range of 60 to 90 was chosen because of

the location of the crossover in slippage and wear properties.

Table I

5	<u>Example</u>	<u>Durometer</u>	<u>Slippage</u>	<u>Wear</u>
10	1	50	5	1
	2	60	5	2
	3	70	4	3
	4	80	4	4
	5	90	2	5

15

In addition, as discussed above, pairs of LIMs, spaced at 80 feet intervals and operated at 480 volts, draws about 15 amps. This is about 90 watts per foot of sorter for about 70 pounds of thrust. Also, a prior art chain drive would draw about 15 watts per foot of sorter for about 1500 pounds of thrust. To the contrary, the present invention drive rollers spaced at 160 feet intervals and operated at 480 volts, draws about 4 amps. This is only about 12 watts per foot of sorter for about 100 pounds of thrust!

30

Certain modifications and improvements will occur to those skilled in the art upon a reading of the foregoing description. For example, while the preferred embodiment described is for a two-axis tilttable cart, many applications could be performed satisfactory using a single axis tilttable cart, as described in the claims. In addition, while a pair of drive motors is preferred, a single motor driving only one of the rollers or a single motor using, for example, a second drive belt to drive the second roller may be satisfactory for some applications. It should be understood that all such modifications and improvements have been deleted herein for the sake of conciseness and readability but are properly within the scope of the following claims.